An Introduction to the MSFC SSM/I Brightness Temperature Data Sets

1. Overview

The Global Hydrology Resource Center (GHRC) has been processing and archiving Special Sensor Microwave / Imager (SSM/I) data since 1990. Prior to May 1995, the SSM/I data source for the GHRC was the National Environmental Satellite Data and Information Service (NESDIS). Since May, 1995, the source has been the Fleet Numerical Meteorology and Oceanography Center (FNMOC). Data is obtained from FNMOC and processed at the GHRC within hours of its reception. Each day full resolution or "swath" brightness temperatures (Tb's) and reduced resolution "gridded" data sets are generated. Browse images of the gridded files are created in both HDF raster and GIF formats. HDF represents the

Hierarchical Data Format, the data format standard for NASA's Earth Observing System Data and Information System.

The GHRC is producing several geophysical products using oceanic SSM/I Tb data including: integrated water vapor, cloud liquid water, and oceanic wind speed. These products are also in swath and gridded formats.

The Department of Defense maintains a series of polar orbiting sun-synchronous meteorological satellites as a part of the Defense Meteorological Satellite Program (DMSP). To date, six of the DMSP satellites have flown an SSM/I, (see Table 1).

Table 1

Satellite	Launch date	NORAD ID/ International ID	SSM/I instrument status
DMSP 5D2-F8	19 June 1987		Operational support ended 13 Aug 1991
DMSP 5D2-F10	1 Dec 1990		Failed, 14 Nov 1997
DMSP 5D2-F11	28 Nov 1991	21798U/91082A	Non-operational as of 8/30/00
DMSP 5D2-F12	29 Aug 1994	23233U/94057A	SSM/I failed soon after launch
DMSP 5D2-F13	24 Mar 1995	23533U/95015A	Operational as of 3/1/02
DMSP 5D2-F14	4 Apr 1997	24753U/97012A	Operational as of 3/1/02
DMSP 5D3-F15	12 Dec 1999	25991U/99067A	Operational as of 3/1/02

The SSM/I is a passive microwave sensor that detects microwave radiation at four frequencies: 19.35 GHz, 22.235 GHz, 37.0 GHz, and 85.5 GHz. The 19, 37, and 85 GHz channels have dual-polarization (vertical and horizontal), while the 22 GHz channel has only vertical polarization. This yields a total of seven channels. The instrument is a conical scanning device sweeping out an approximately 1400 km wide swath as it looks forward (F8 looks backward) at an angle of about 45 degrees from vertical. The instrument scans through 102 degrees for each scanning revolution. The scan period is 1.899 seconds.

The 85 GHz channels scan continuously, while the 19, 22, and 37 GHz channels sample every other element of every other scan. The scan on which all channels are sampled is termed the A-scan and the 85 GHz-only scan is called the B-scan. The A- and B-scans are referred to as a scan-pair. Because of these sampling characteristics, there are 64 low frequency samples and 128 high frequency samples in each A-scan. There are one-fourth as many elements in a low frequency (19, 22, or 37 GHz) swath than in a high frequency (85 GHz) swath.

Table 2 (from the SSM/I Calibration and Validation Final Report) shows footprint sizes and sampling resolutions for all four frequencies.

Table 2

Frequency	Appr. Footprint Size		Footprint Sampling Resolution
	Along-track	Along-scan	
19 GHz	69 km	43 km	25 km
22 GHz	60	40	25
37 GHz	37	28	25
85 GHz	15	13	12.5

The GHRC archives data from F10, and is currently processing and archiving SSM/I data from F13, F14, and F15. Table 3 shows typical values for some orbital characteristics of these DMSP satellites.

Table 3

Parameter	F10	F13	F14	F15
Ascending equator-crossing time (UTC)	22:25 as of 1/1/99	18:14 as of 3/1/02	20:24 as of 3/1/02	21:32 as of 3/1/02
Period (min)	100.7	101.9	101.9	101.8
Altitude Max. (km)	853	855	855	865
Altitude Min. (km)	740	844	842.5	844
Orbit Eccentricity	0.00814	0.00073	0.00086	0.00098

UTC represents Universal Coordinated Time.

Since the orbital period for all DMSP satellites shown in Table 3 is about 102 minutes, each DMSP orbits the earth about 14.1 times per day. The GHRC processing breaks the SSM/I data stream into passes. A pass is defined as a pole-to-pole swath that is either ascending (south to north) or descending (north to south). A complete pass contains about 51 minutes of data or about 1610 A and B-scans. (NOTE: the F10 satellite, because of its orbital eccentricity, has a larger variation in the number of scans per pass.) The first pass of a UTC day is defined as the *first complete pass* of the day. The last pass processed is the *last complete pass beginning in the day being processed*. Be aware that the last pass will almost always contain some data from the next UTC day. If there are <u>any</u> data for a pass, the output files are created and all missing scans are flagged. A typical day contains 28 or 29 passes.

For more information about the satellites, refer to the GHRC Home Page's documentation on DMSP-F8, F10, F11, F12, F13, F14, and F15.

For more information about the SSM/I instrument, refer to: <u>SSM/I</u>.

2. Processing Steps

2.1 Swath Data

2.1.1 Data Acquisition

The source of the GHRC's SSM/I data is FNMOC. FNMOC is the Department of Defense's (DoD) center of expertise for DMSP passive microwave data processing. The DoD has an agreement with the National Oceanographic and Atmospheric Administration (NOAA) under which they share data via the Shared Processing Network (SPN). FNMOC generates SSM/I antenna temperature files known as Temperature Data Records (TDR's) and sends them to NOAA/NESDIS. NESDIS performs minimal file unpacking and makes the data available to the GHRC. Files are usually available within 1 hour (or less) of data acquisition by FNMOC.

2.1.2 Data Quality Control

Each day the GHRC performs a four step quality control process on the previous day's data. These steps are:

1. Date stamping
2. File merging
3. Navigation checking
4. Calibration checking

Step 1, date stamping, is necessary because each scan-pair of data has a "time" stamp, but not a "date" stamp. This step removes all data not from the day being processed.

Step 2, file merging, combines all of the data files from a specified day. During this process, data gaps are filled with flagged values.

Step 3, navigation checking, uses an orbit prediction model to determine the proper latitude and longitude of the 85 GHz mid-scan pixel at a given time. That element's latitude and longitude values are compared to the model results, and if they are not within a specified distance, the entire scan-pair is flagged as mislocated.

Internal checks are also performed in this step on the latitude and longitude values to look for "glitches" or dramatic changes. For instance, if two consecutive scan-pair longitude values show eastward motion, the second scan-pair's latitude, longitude, and surface type values are flagged as questionable. The antenna temperature values are left unchanged.

Step 4, calibration checking, checks the hot and cold load counts for each scan and each channel. If a bad hot or cold load count is found, and since 10-scan-pair averaging has been applied by FNMOC, ten scan-pairs of antenna

temperatures are flagged for that specific channel, (the scan-pair at which the bad calibration occurred and the 9 previous scan-pairs). The three hot load thermistor temperatures are also checked, but if only these are bad, only the current scan-pair is flagged.

2.1.3 Data Processing

After these QC steps, data are read for each pass (ascending or descending), sequentially for an entire day. Antenna temperatures are then converted to brightness temperatures (Tb's) using Remote Sensing System's antenna pattern correction (APC), along-scan bias corrections, and the F8-F10 intercalibration. The output for each execution of the software is:

1. one pass file with brightness temperatures (Tb)
2. one pass file with high resolution geolocation information (hn)
3. one pass file with low resolution geolocation information (ln), associated with the low frequency channels.

In addition, on each execution an ASCII text file is written containing summary information of each pass. This provides a quick look of the day's processing.

2.2 Gridded Data

All of the swath files containing ascending passes are averaged into a 0.5 x 0.5 degree global grid (720 x 360). The same is done for descending passes. The global grid is centered on the Greenwich meridian. Each grid box value is the mean of the SSM/I brightness temperatures located within the half degree box centered at every xx.25 and xx.75 degrees. Only valid brightness temperatures are used. Table 4 lists some representative grid points and their geographic extents.

Table 4

Array Coords. (Y,X)	Centered at Earth Coords.	Latitude Extent Earth Coords.	Longitude Extent Earth Coords.
1, 1	89.75,-179.75	90.00 - 89.51	-180.00 - -179.51
180,360	0.25, -0.25	0.50 - 0.01	-0.50 - -0.01
181,360	-0.25, -0.25	0.00 - -0.49	-0.50 - -0.01
181,361	-0.25, 0.25	0.00 - -0.49	0.00 - 0.49
180,361	0.25, 0.25	0.50 - 0.01	0.00 - 0.49
360,720	-89.75, 179.75	-89.50 - -90.00	179.50 - 179.99

2.3 Browse Images (HDF, GIF)

The HDF gridded data files are used to create HDF raster(8) images. These images do not contain scientific data, but instead contain only color values. GIF images are then created from the HDF raster images. There are 14 HDF raster files and 14 GIF files (ascending and descending files for each channel) generated per day.

3. Brightness Temperature Files

3.1 File Names

The brightness temperature pass file naming convention is:

```
fxx_Tb_yyddd_ppZ.hdf.gz
fxx_ln_yyddd_ppZ.hdf.gz
meta_fxx_yyddd.text
```

where

xx is the satellite ID number (10, 13, 14, or 15)
yyddd is the date; year (yy) and day (ddd)
pp is the pass number (01-29)
Z is the pass direction (A-ascending or D-descending)
hdf since it is an HDF file
gz since is has been compressed using the "gzip" utility

For example, the file "f10_Tb_95139_05D.hdf.gz" contains F10 brightness temperature data from the 5th pass (descending) of day 95139. The corresponding high-resolution geolocation data for this pass is in "f10_hn_95139_05D.hdf.gz"

3.2 File Content

HDF files contain data grouped within the file called "objects". Table 5 lists the objects in the brightness temperature HDF file. The dimension 'N' represents the number of A- and B-scans in the pass, nominally 1570 - 1616, and can be retrieved with a simple HDF library call. (See section 7) All objects are filled with missing scans where needed. HDF labels are provided with each object.

Table 5

Description	units	scale	format	type	size
Day of year	day	1	ddd	integer*2	(1 x N)

Time of day	seconds	1	sssss.ssss	real*4	(1 x N)
19 GHz vertical Tb	K	100	ttttt	integer*2	(64 x N/2)
19 GHz horizontal Tb	K	100	ttttt	integer*2	(64 x N/2)
22 GHz vertical Tb	K	100	ttttt	integer*2	(64 x N/2)
37 GHz vertical Tb	K	100	ttttt	integer*2	(64 x N/2)
37 GHz horizontal Tb	K	100	ttttt	integer*2	(64 x N/2)
85 GHz vertical Tb	K	100	ttttt	integer*2	(128 x N)
85 GHz horizontal Tb	K	100	ttttt	integer*2	(128 x N)
Spacecraft position					(5 x N/2)
-Time(Minute vector)	seconds	1	sssss.s	real*4	
-Latitude	degrees	1	ddd.dd	real*4	
-Longitude	degrees	1	ddd.dd	real*4	
-Altitude	meters	1	dddddd.	real*4	
-Incidence Angle	degrees	1	dd.dd	real*4	
Two-line element set	vary	NA	c	integer*1	(69 x 2)
McIDAS Nav. directory	vary	NA	xxxxxx	integer*4	(1 x 128)
Pass Metadata	See NOTE			integer*4	(1 x 512)

In the Spacecraft Position Vector array, missing scans are flagged with -999.0. Since the values are floating point, no scaling is done. Times are in seconds (to the nearest half second), latitudes range from 0.00 to 180.00 degrees, longitudes are positive east from -180.00 to 180.00 degrees, and altitudes are in whole meters. The two-line element set (object #12) contains a two-line formatted group of ephemeris values closest in time to 1200 UTC of the day being processed. The GHRC retrieves two-line element sets daily. The McIDAS Navigation directory (object #13) is for use with McIDAS software. NOTE: See Pass Metadata object for information about the Pass Metadata object (object #14).

3.3 Data Values

The brightness temperature data in the HDF files are integer*2, ranging from -32768 to 32767. Table 6 shows possible values of brightness temperatures. **Note: <u>Time of day</u> values are negated for several conditions – see Table 8-A.**

Table 6

Value	Represents
-11	Missing scan-pair
-20	Misdirected scan-pair
-21	Erroneous value found in latitude

-90	-1 K < Ta < 1 K
-91	-1 K < Tb < 1 K
-94	Cal_Bad and any Ta < -1
-95	Cal_OK and one polarization Ta < -1
-98	Cal_OK and both polarization's Ta < -1
-99	Cal_OK and Tb < -1
< -100	A positive input Ta flagged due to Cal_Bad (scaled by 100) one polarization bad and Cal_OK (scaled by 100)
> 100	100 valid Tb (scaled by 100)

4. High Resolution Geolocation (hn) Files

4.1 File Names

The high resolution geolocation pass file naming convention is:

f*xx*_hn_*yyddd_ppZ*.hdf.gz

where

xx is the satellite ID number (10, 13, 14, or 15)
yyddd is the date; year (yy) and day (ddd)
pp is the pass number (01-29)
Z is the pass direction (A-ascending or D-descending)
hdf since it is an HDF file
gz since it has been compressed using the "gzip" utility

For example, the file "f13_hn_95165_27D.hdf.gz" contains F13 high resolution geolocation data from the 27th pass (descending) of day 95165. It corresponds to the brightness temperature data in "f13_Tb_95165_27D.hdf.gz"

4.2 File Content

Table 7 lists the objects in the high resolution geolocation HDF files. The dimension 'N' represents the number of A- and B-scans in this pass (nominally 1570 - 1616) and can be retrieved with a simple HDF library call. All objects are filled with missing scans where needed. Labels are provided with each object.

Table 7

Description	units	scale	format	type	size
Day of year	day	1	ddd	integer*2	(1 x N)
Time of day	seconds	1	sssss.ssss	real*4	(1 x N)
Latitude	degrees	100	ddddd	integer*2	(128 x N)
Longitude	degrees	100	ddddd	integer*2	(128 x N)
Surface Type	class	1	c	integer*1	(128 x N)

4.3 Data Values

All latitude and longitude data are scaled by 100. Latitude is positive north (-9000 to 9000) and longitude is positive east (-18000 to 18000).
Tables 8-A and 8-B show Latitude, Longitude, & Surface type values in "hn" files.

* **Time of day** values are negated for these situations.

Table 8-A

Value	Latitude	Longitude	Value
-9011	Missing scan-pair*	Missing scan-pair*	-18011
-9020	Misdirected scan-pair	Misdirected scan-pair	-18020
-9021	Nearby bad latitude value	Nearby bad latitude value	-18021
-9022	Mislocated scan-pair*	Mislocated scan-pair*	-18022
-9033	Questionable Lat &/or Lon scan-pair*	Questionable Lat &/or Lon scan-pair*	-18033
-9000 < Lat < +9000	Valid Latitude	Valid Longitude	-18000 < Lon < +18000

Table 8-B

Value	Surface type
-11	Missing scan-pair
-20	Misdirected scan-pair
-21	Nearby bad latitude value
-22	Mislocated scan-pair
-33	Questionable Lat &/or Lon scan-pair
0	Land
1	Vegetation/land
2	Near-coast
3	Ice

4	Possible ice
5	Water
6	Coast
7	Not used

5. Low Resolution (ln) Files

5.1 File Names

Low resolution geolocation files are created for users who either do not need high resolution information or are using geophysical products, most of which are generated at the resolution of the low frequency channels (19, 22, and 37 GHz). The low resolution geolocation pass file naming convention is:

`fxx_ln_yyddd_ppZ.hdf.gz`

where

xx is the satellite ID number (10, 13, 14, or 15)
yyddd is the date; year (yy) and day (ddd)
pp is the pass number (01-29)
Z is the pass direction (A-ascending or D-descending)
hdf since it is an HDF file
gz since it has been compressed using the "gzip" utility

For example, the file "f13_ln_95299_27A.hdf.gz" contains F13 low resolution geolocation data from the 27th pass (ascending) of day 95299. It corresponds to the brightness temperature data (B-scan only) in "f13_Tb_95299_27A.hdf.gz"

5.2 File Content

Table 9 lists the objects in the low resolution geolocation HDF files. The dimension 'N' represents the number of A-scans in this pass (nominally 785 - 808) and can be retrieved with a simple HDF library call. All objects are filled with missing scans where needed. Labels are provided with each object.

Table 9

Description	units	scale	format	type	size
Day of year	day	1	ddd	integer*2	(1 x N)

Time of day	seconds	1	sssss.ssss	real*4	(1 x N)
Latitude	degrees	100	ddddd	integer*2	(64 x N)
Longitude	degrees	100	ddddd	integer*2	(64 x N)
Surface Type	class	1	c	integer*1	(64 x N)

5.3 Data Values

All latitude and longitude data are scaled by 100. Latitude is positive north (-9000 to 9000) and longitude is positive east (-18000 to 18000).
Tables 8-A and 8-B show Latitude, Longitude, & Surface type values in "ln" files.

6. Gridded Files

6.1 File Names

The files are in the Hierarchical Data Format (HDF). Each HDF file has also been compressed using the GNU gzip utility. The file naming convention is:

f*xx*_Tb_*yyddd*_dayAD.hdf.gz

where

yyddd is the date; year (yy) and day (ddd)
xx is the satellite ID number (10, 13, 14, or 15)

For example, the file "f10_Tb_95155_dayAD.hdf.gz" contains gridded F10 brightness temperatures for day 95155. The 'AD' in the filename represents the fact that the ascending and descending passes are computed separately and placed in two images.

6.2 File Content

Table 10 lists the objects in the HDF files and their contents.

Table 10

Description	units	scale	format	type	size
V19 ascending grid	K	100	ttttt	integer*2	(360 x 720)
H19 ascending grid	K	100	ttttt	integer*2	(360 x 720)
V22 ascending grid	K	100	ttttt	integer*2	(360 x 720)
V37 ascending grid	K	100	ttttt	integer*2	(360 x 720)

H37 ascending grid	K	100	ttttt	integer*2	(360 x 720)
V85 ascending grid	K	100	ttttt	integer*2	(360 x 720)
H85 ascending grid	K	100	ttttt	integer*2	(360 x 720)
V19 descending grid	K	100	ttttt	integer*2	(360 x 720)
H19 descending grid	K	100	ttttt	integer*2	(360 x 720)
V22 descending grid	K	100	ttttt	integer*2	(360 x 720)
V37 descending grid	K	100	ttttt	integer*2	(360 x 720)
H37 descending grid	K	100	ttttt	integer*2	(360 x 720)
V85 descending grid	K	100	ttttt	integer*2	(360 x 720)
H85 descending grid	K	100	ttttt	integer*2	(360 x 720)
Gridded Metadata	See NOTE			integer*4	(31 x 512)

Note: See Gridded Metadata object for information about the Gridded Metadata object (object #16).

6.3 Data Values

The brightness temperature data in the gridded HDF files are integer*2. Table 11 shows possible values.

Table 11

Value	Represents
-1	Flagged due to missing, mis-located, or bad calibration
>0	valid Tb (scaled by 100)

7. Browse Files (HDF, GIF)

Browse files are generated from the daily gridded data in two formats, HDF raster-8 and GIF. There is only one image per file. The file naming conventions are:


```
fxx_ccc_yyddd_dayZ_ras8.hdf
fxx_ccc_yyddd_dayZ_ras8.gif
```

where

xx is the satellite ID number (10, 13, 14, or 15)
ccc is the channel (V19, H19, V22, V37, H37, V85, H85)
yyddd is the date; year (yy) and day (ddd)

Z is the pass direction (A-ascending or D-descending)
hdf indicates an HDF raster image file
gif indicates a GIF image file

For example, the file "f10_H37_95002_dayD.ras8.hdf" contains an HDF raster8 image of the F10 H37 brightness temperatures for the descending passes of day 95002. HDF-Raster8 files are in the HDF 8-bit raster image format. They each contain one 8-bit raster image, a palette, a file description, and a legend.
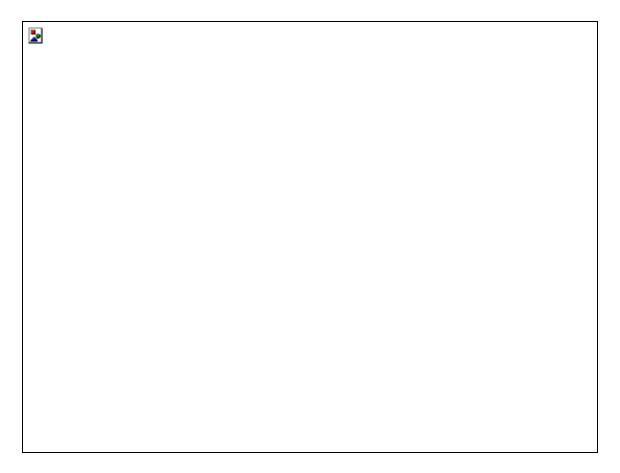
GIF files are in the Compuserve GIF image format. They each contain one annotated image.

8. File Access

SSM/I data processed by the GHRC are available online via the GHRC Home Page (click on the LIS SCF folder under the Dataset List page and click on the **browse** icon beside any of the **MSFC SSM/I** datasets.)
You may use FTP to go directly to the anonymous ftp site. The ftp address is

ghrc.msfc.nasa.gov

Use `anonymous` as the Username and your e-mail address as the password. If you'd like to use your browser to go there now, click here. There is a "data" branch of the server containing swaths and gridded data and a "browse" branch containing GIFs and HDF-raster8 files. The directory structure is shown below.

8.1 Sample Programs

Two sample FORTRAN program have been provided to read swath and gridded data. *read_ssmi_tb.f* is for reading Tb swath files while *read_ssmi_tb_grid.f* is for reading Tb grid files. They will read a file and fill arrays containing various data and metadata. The HDF software library is required (see below).

9. HDF Library and Tools

HDF is a library and platform independent data format for the storage and exchange of scientific data. It includes Fortran and C calling interfaces, and utilities for analyzing and converting HDF data files. HDF is developed and supported by the National Center for Supercomputing Applications (NCSA) and is available in the public domain (http://hdf.ncsa.uiuc.edu/). HDF stands for Hierarchical Data Format. It is a multi-object file format for the transfer of graphical and numerical data between machines. HDF is a portable file format. HDF files can be shared across platforms. An HDF file created on one computer, say a Silicon Graphics Indy (SGI), can be read on another system, say IBM PC, without modification.

9.1 How to Obtain the HDF Library

The HDF library and tools can be down loaded from the World Wide Web at:

http://hdf.ncsa.uiuc.edu/

Follow the instructions given there.

9.2 Visualization Software

The HDF files were created using HDF version 3.3, release 4. They have been successfully viewed with collage (v1.3 and v1.3.1 from the National Center for Supercomputing Applications (NCSA)). Some other visualization companies are currently working to upgrade all their software to work with files created with this release of HDF.

The GIF images may be viewed by most popular GIF image viewers.

10. Contact Information

For more information or to obtain data, contact:

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Huntsville, AL 35805

Phone: 256-961-7932
FAX: 256-961-7723
E-mail: ghrc@eos.nasa.gov

11. References

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